An Integrated Prototyping and Simulation Architecture for Space Specific Protocol Developments and Verifications

Fraunhofer Institute for Open Communication Systems

An Integrated Prototyping and Simulation Architecture for Space Specific Protocol Developments and Verifications

Marc Emmelmann, emmelmann@ieee.org

Fraunhofer Institute for
Open Communication Systems

NASA 3nd Internet Space Workshop

Cleveland, OH, USA

June 4—6, 2003

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Outline

Introduction
- Project Framework
- System Design with Reduced Development Costs

System Architecture
- Integrated Development Flow (Overview)
- Simulation on Network Level
- Protocol Prototyping and Verification

Use Cases
- ATM-Sat MAC Protocol Development
- ATM connectivity between ISS Columbus and Earth

Summary & Outlook

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Introduction
Project Framework

ATM-Sat Project	- System Design and Study of an ATM-based LEO Satellite System for Multimedia Applications - Financed by German Ministry for Education and Research (BMBF)
ATM-Sat Partners	- German Aerospace Agency (DLR), and - Tesat Spacecom (formerly BOSCH SatCom)
Project Constraints	- None: ATM-Sat mere research project - Commercial aspects discussed: reduce development costs while still designing failure save systems

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Introduction
System Design with Reduced Development Costs

Possible Solution	- Usage of commercial of the shelf equipment for development and simulation - Standard operation systems as target systems - Design re-usable components
Integrated Dev. Approach	- Idea by Fraunhofer FOKUS - Supported by TU Berlin (Research Group for Open Communication Systems, OKS)

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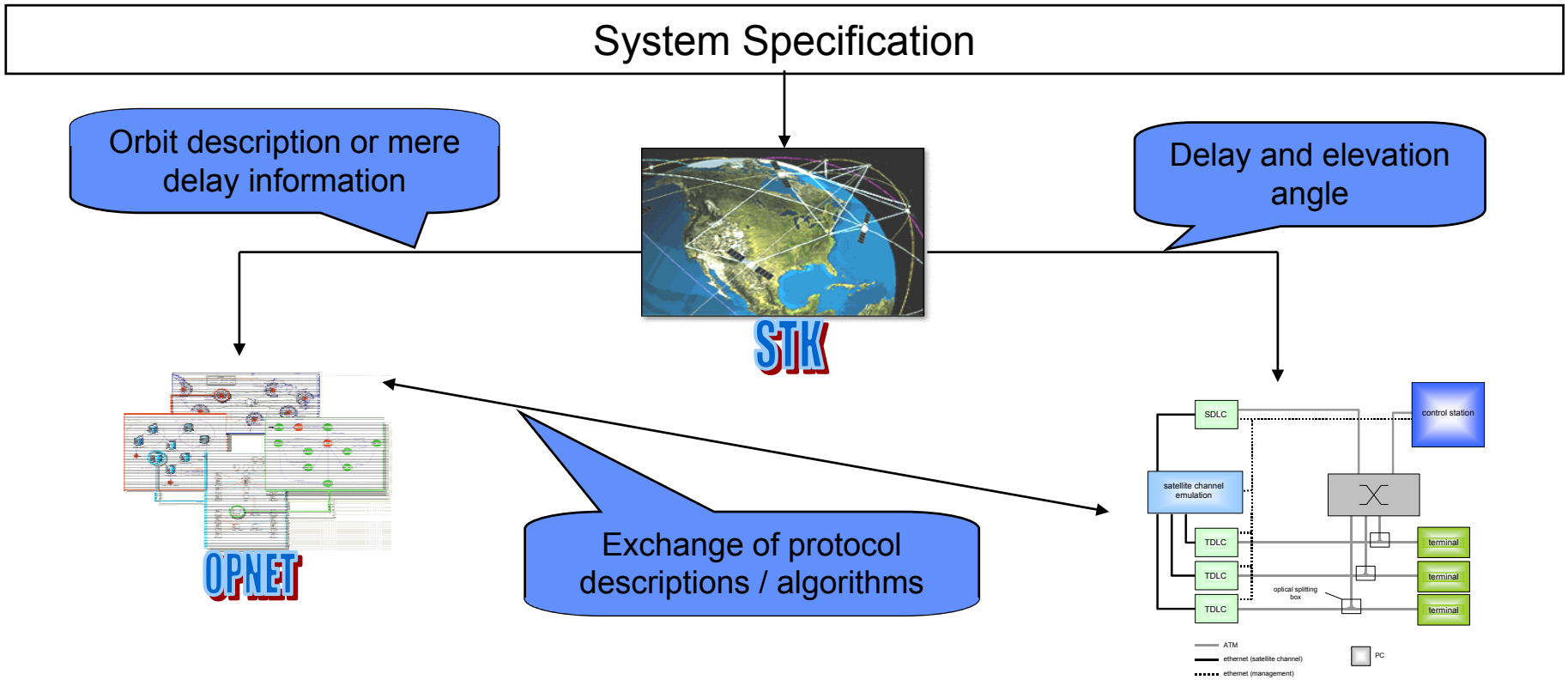
System Architecture
Integrated Development Flow (Overview)



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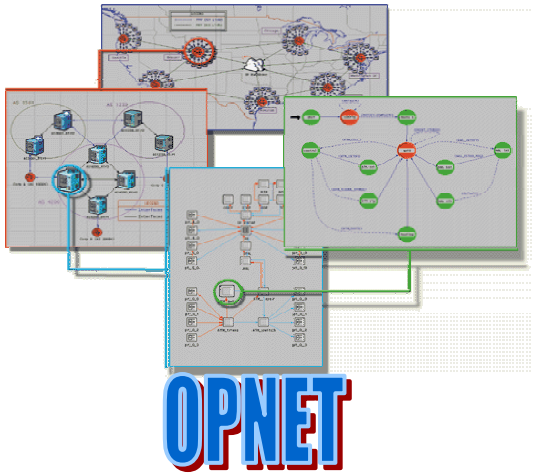
System Architecture
Simulation on Network Level



- Focus on the entire communication network (large scale network simulation)
- Performance evaluation and dimensioning of envisioned system
- Analysis of interaction with other network types
- New protocols and algorithms “encapsulated” in processes and programmed in C

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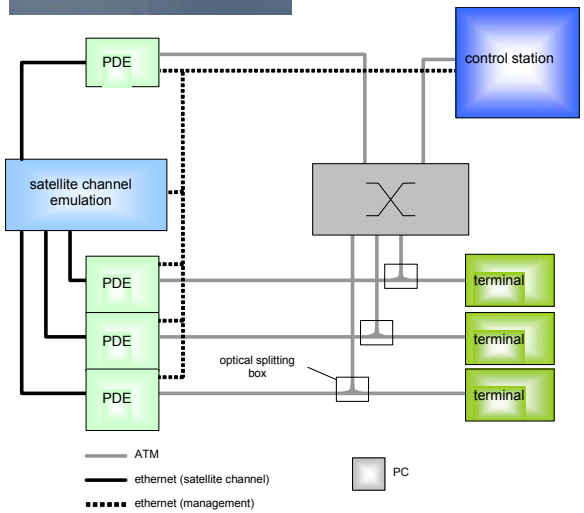
System Architecture
Protocol Prototyping and Verification



Key Features:

Std. COTS components
Focus on target system
FreeBSD 5 current-version

Core Units:

` Sat. channel emulator

Configurable via SNMP
Adds variable delay
Packet corruptions

Protocol Dev. Entity

"External VSAT System"
Netgraph used for devel.

Control Station

Time synchronization (NTP)
Initializes SCE & PDE

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Use Cases
ATM-Sat MAC Protocol Development

Development Steps

- Specification (SDL based)
- Simulation (with Opnet)
- Implementation (using the Prototyping and Simulation Architecture)

Most complex scenario which incorporates all aspect of the integrated design and development work flow and all possible functionalities of the Prototyping and Simulation Environment.

Opnet Simulation

- Conducted by DLR
- Focus on large scale networks and scheduling

Target System MAC

- Implemented by Fraunhofer FOKUS
- Focus on performance
- Used for demonstrations

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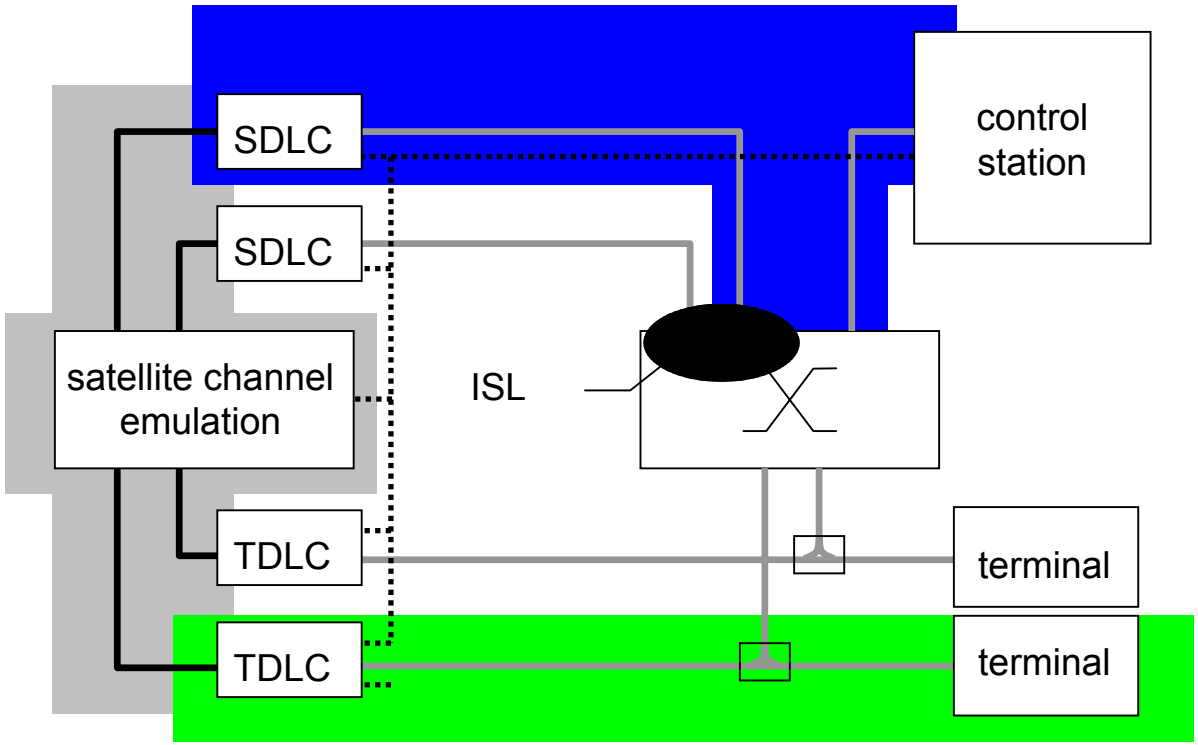
Use Cases
ATM-Sat MAC Protocol Development

two terminal in different footprints

satellite

satellite channel

application terminal



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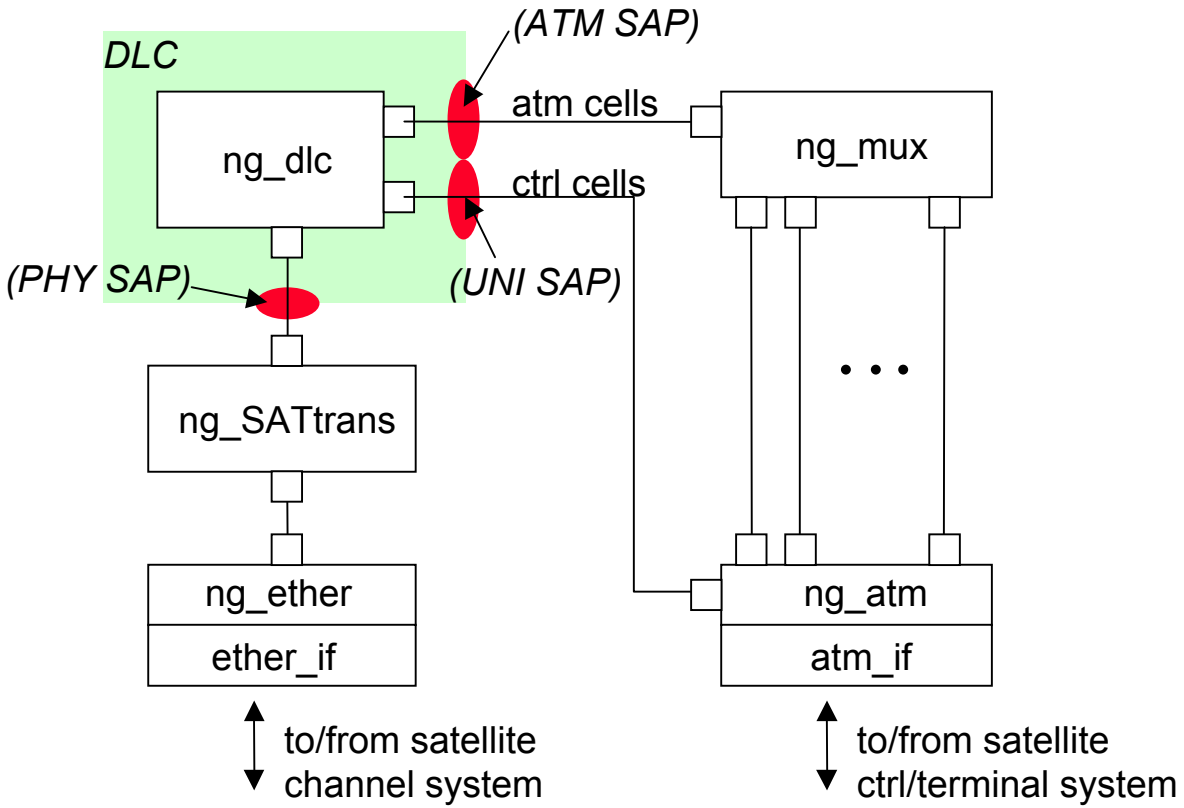
Demonstrator
DLC System

DLC layer node with three SAPs (ng_dlc)

convergence layer for ethernet encapsulation (ng_SATtrans)

multiplexer for ATM connections between DLC system and terminal system (ng_mux)

ATM cells from separate PVC for UNI messages are directly forwarded to the DLC layer



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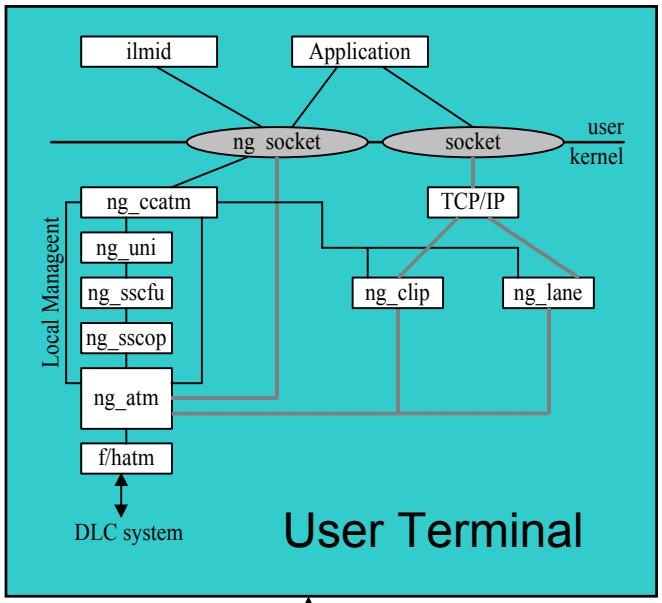
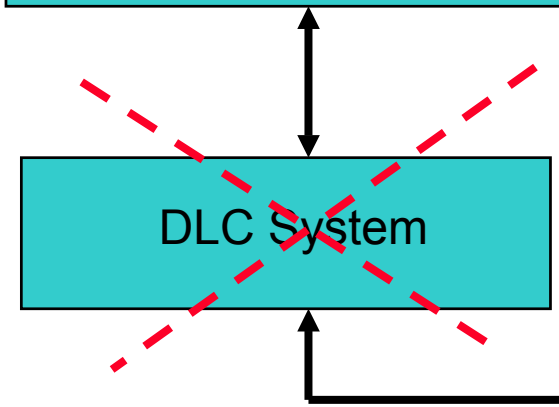
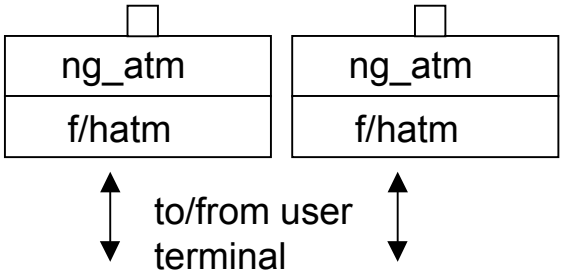
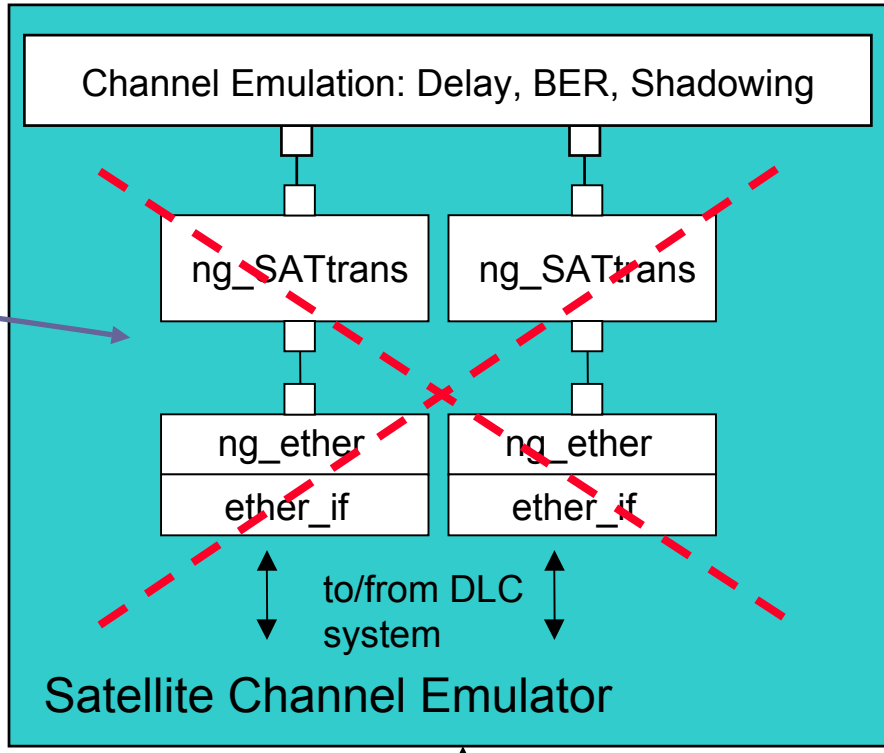
Use Cases
ISS Columbus ATM connectivity









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Interaction between Opnet and the Protocol Development Entity

Opnet	- Encapsulates algorithms and protocols in “Process-Nodes” - Input combination of FSMs (graphical input) and C
PDE	- Applies Netgraph concept of FreeBSD 5.0 current → encapsulation of algorithms / protocols - Encapsulation is by nature split into two files: File a) Source code of algorithm / protocol File b) Hookup with Netgraph system
Code Sharing	- Currently by hand, restricted to some algorithms - Common code basis seems to be possible, - Requires “remapping” function calls

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Summary & Outlook

Integrated Simulation & Prototyping System	- Evaluation and dimensioning of entire network - Protocol development wrt. target system - Already fully integrated environment for development, testing, and demonstration of target system protocols - Partial code exchange between Opnet and PDE done, common code basis seems feasible
Future Work	- Common code basis - Determine how performatory target system code is in the simulator - Determines on follow-up projects
Further Information	- emmelmann@ieee.org - http://www.fokus.fraunhofer.de/cats/satellite

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Acronyms

ATM	Asynchronous Transfer Mode
COTS	Commercial Of-The-Shelf
CS	Control Station
DLC	Data Link Control
ISL	Inter-Satellite-Link
MAC	Medium Access Control
PDE	Protocol Development and Prototyping Entity
PVC	Private Virtual Channel
SCE	Satellite Channel Emulator
SDLC	Satellite DLC
TDLC	Terminal DLC
ISS	International Space Station
NTP	Network Timing Protocol
SAP	Service Access Point
VSAT	Very Small Aperture

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References & Further Reading

- http://www.fokus.fraunhofer.de/cats/satellite

- J. Bostic, “Report on OPNET simulations,” German Aerospace Agency (DLR), Oberpfaffenhofen, Germany, Tech. Rep. DLR-IB, IB 554-01/02.

- Marc Emmelmann, “Effects of advertised receive buffer size and timer granularity on TCP performance over erroneous links in LEO satellite networks,” in Proc. IEEE Globecom ’02, Taipei, Taiwan, Nov. 17-21, 2002.

- http://www.opnet.com
- http://www.stk.com
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- http://www.freebsd.org
- http://www.daemonnews.org/200003/netgraph.html

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Supportive Slides

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Simulation Environment
Simulation Workflow

STK

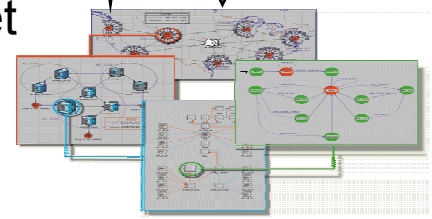
Definition of satellite network
- Orbit altitude
- Orbit type

Satellite Path Description

AER Data → Parser Programs

p2p-link w/ variable delay ← *.c and *.h Files for pipeline stages

Opnet



Definition of communication network aspects
- Bandwidth
- Bit Error Rates
- Internet Protocol Suite

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Satellite System Architecture
System Parameters

LEO satellite network

70 ... 100 satellites

one satellite connected to 4 neighbors via optical ISLs (inter- and intra-orbit)

ISLs existing all the time

dynamic bandwidth allocation

2400 ... 300000 user per satellite depending on the allocated bandwidth

Uplink bitrate	fixed and portable terminals: up to 2048 kbit/s mobile terminals: up to 384 kbit/s in steps of 16 kbit/s
Downlink bitrate	up to 32786 kbit/s in steps of 16 kbit/s
Modulation scheme	QPSK
Access scheme	uplink: MF-TDMA downlink: TDM
Spotbeam diameter	50 km – 500 km
Satellite switch capacity	5 Gbit/s - 10 Gbit/s
ISL capacity	7 Gbit/s - 10 Gbit/s
Downlink data rate per carrier	32 Mbit/s
Maximum number of downlink channels per carrier	32Mbit/s / 16kbit/s = 2000

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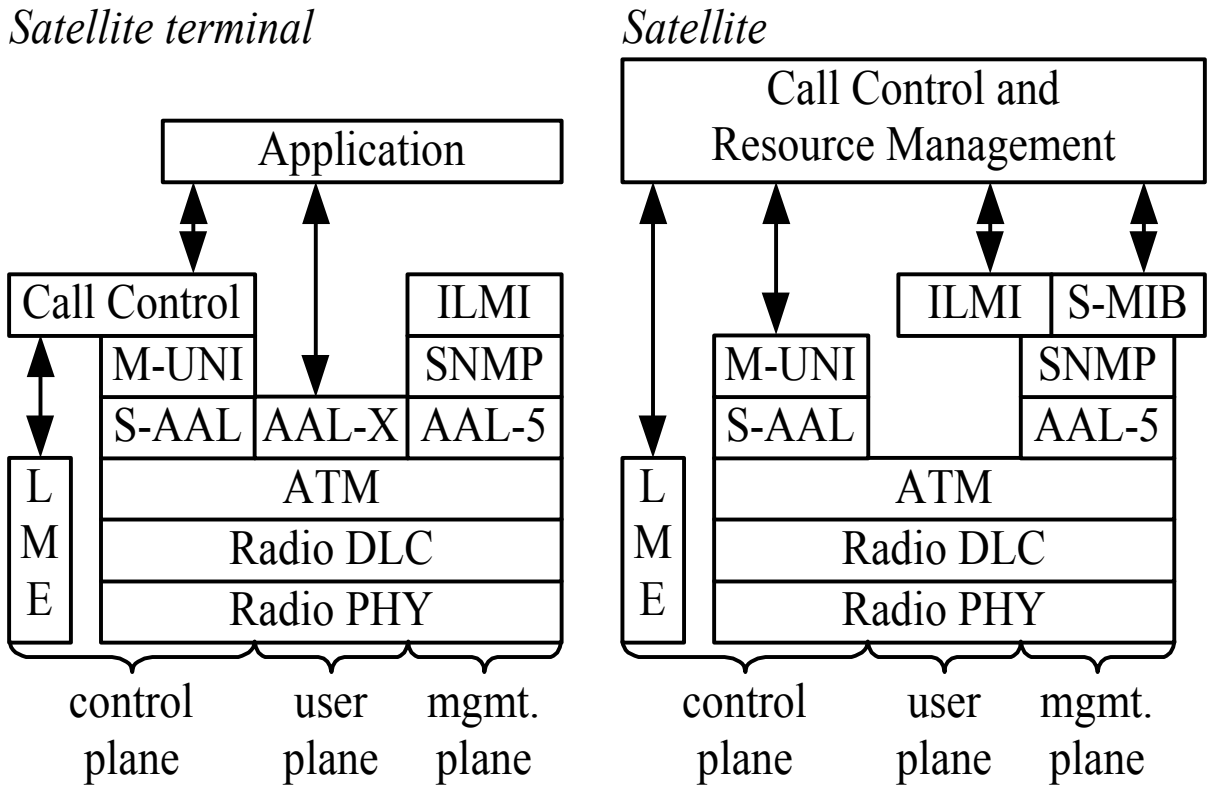
Satellite System Architecture
Protocol Architecture

standard ATM is used

modified ATM signaling is used due to limited onboard processing power and unnecessary protocol functions

DLC layer with a management interface to upper layer is implemented



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Demonstrator
User Terminal

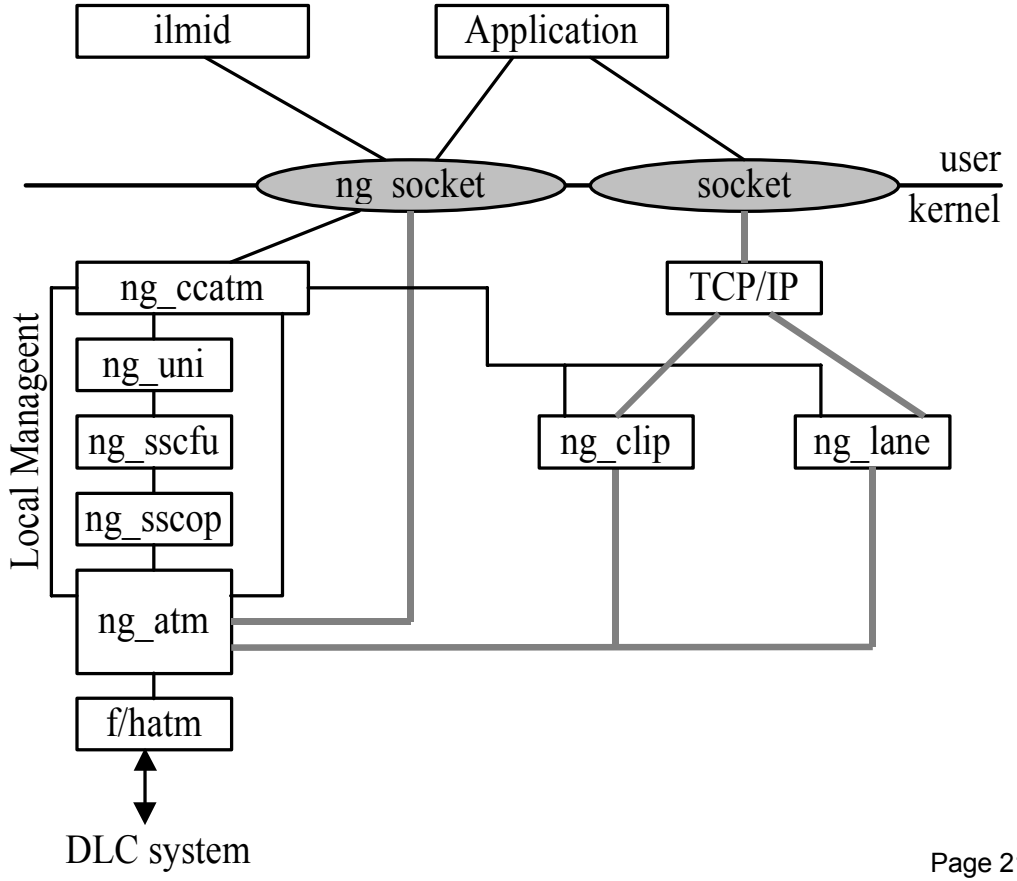
FreeBSD netgraph subsystem used for entire ATM signaling stack

applications can access ATM directly or via usual TCP/IP

IP realised via CLIP and ATM Forum LAN emulation

local management interface (UNI <-> DLC) implemented via a PVC between the systems

of-the-shelf IP and native ATM applications can be demonstrated



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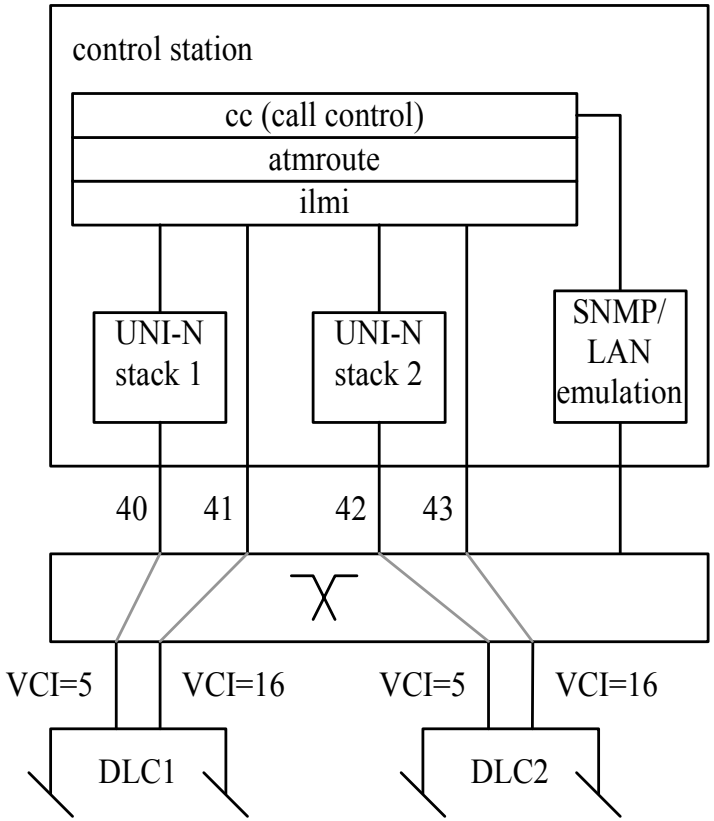
Demonstrator
Control Station



console server for the DLC systems and the ATM switch

signaling VCs are forwarded as PVCs to the control station preforming the signaling

call control daemon is built around an SNMP daemon

management station for the complete demonstrator

can run many tracing tools for measurements

diskless boot support for DLC systems

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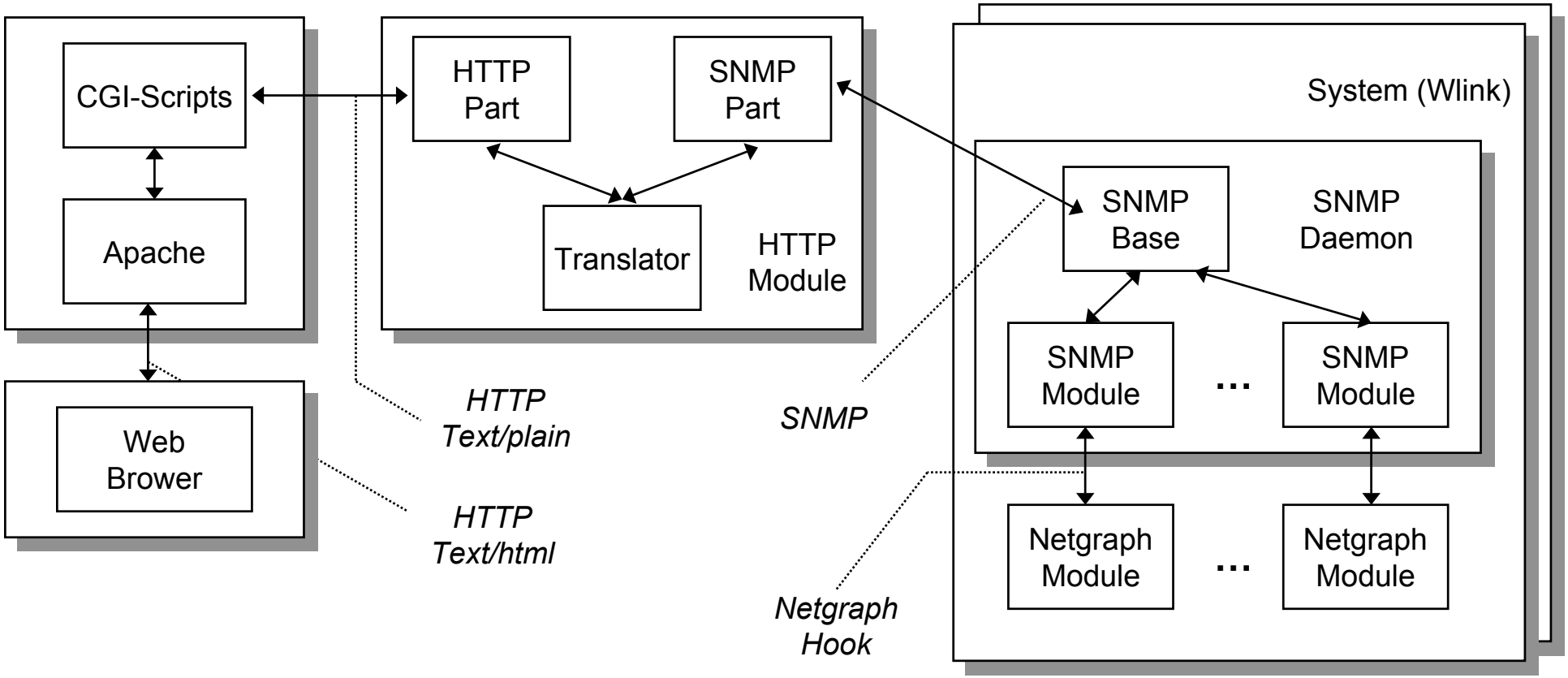
Demonstrator
Management (Internal Structure)



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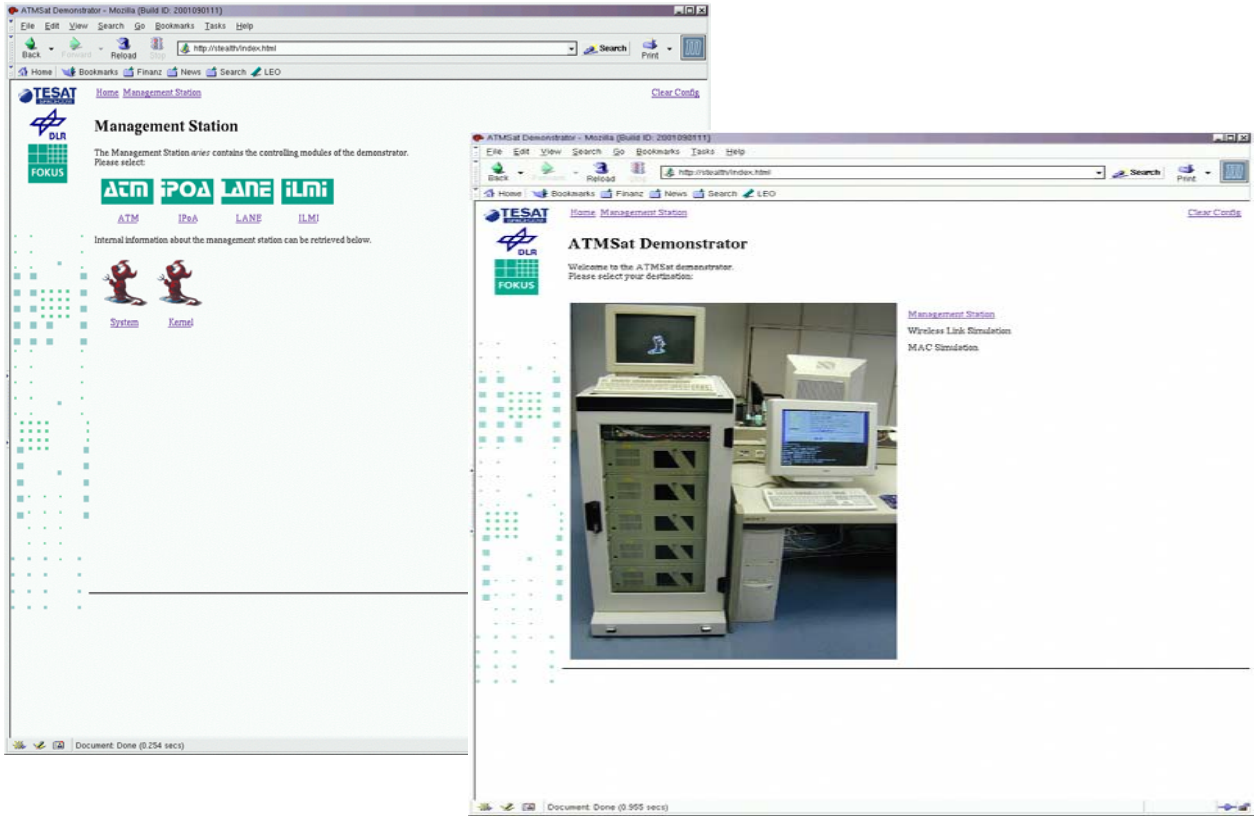
Demonstrator
Management (Graphical User Interface)

Compatible with almost all browsers with frame support

For simplicity, only minimum set of HTML features used

Working Page divided in two zones: top part for navigation and status reports, bottom part for setting parameters

Optional additional reporting windows and periodic refresh



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